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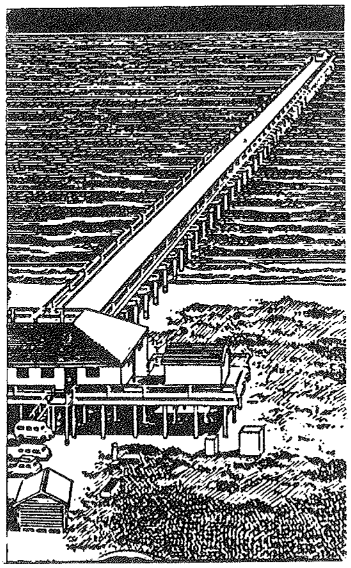

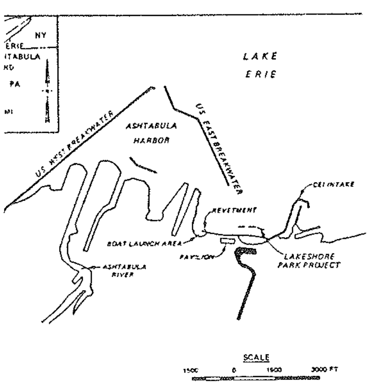

MISCELLANEOUS PAPER CERC-89-5

THE LAKESHORE PARK, ASHTABULA, OHIO, BREAKWATER PROJECT

by

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April 1989
Final Report

Approved For Public Release; Distribution Unlimited

Prepared for DEPARTMENT OF THE ARMY
US Army Corps of Engineers
Washington, DC 20314-1000

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Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0188
Exp. Date Jun 30, 1986

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) Miscellaneous Paper CERC-89-5	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION USAEWES, Coastal Engineering Research Center 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) PO Box 631 Vicksburg, MS 39181-0631	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION US Army Corps of Engineers 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code) Washington, DC 20314-1000	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO. 31232

11. TITLE (Include Security Classification)
The Lakeshore Park, Ashtabula, Ohio, Breakwater Project

12. PERSONAL AUTHOR(S)
Rosati, Julie Dean; Pope, Joan; Bender, Thomas; Truitt, Clifford L.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final report	FROM ______ TO ______	April 1989	33

16. SUPPLEMENTARY NOTATION Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Beach fill Breakwaters Shore protection

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This report documents the bathymetric and shoreline response to a three-segment detached breakwater and beach-fill shore protection project constructed in 1982 at Lakeshore Park, Ashtabula, OH. The beach fill was rapidly lost from the project area, and a monitoring program was established in 1984 to document the loss of beach material and to evaluate the performance of the project. Data collected during the monitoring program include bathymetric surveys, aerial photography, and Littoral Environment Observation (LEO) data.

Results from the monitoring program and subsequent analysis indicate that the placed beach material was finer graded than was specified; the majority of this material was shoaled in a boat launch area at the western end of the park. Based on LEO data, a volume change analysis, and a frequent need in the postproject period to dredge the boat launch area at the western end of the park, an east to west direction of sediment transport was

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20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code) / 22c. OFFICE SYMBOL

19. ABSTRACT (Continued).

indicated. Comparisons with other segmented detached breakwater projects indicate that performance of the Lakeshore Park structures may be improved by adding stone to decrease the gap width between segments or to increase the crest elevation.

Recent modifications to Lakeshore Park, two groins built at either end of the project area and coarser graded beach fill, are discussed in the report. Based on results from the monitoring program, the west groin should present an effective trap for littoral sediment provided it extends out to intercept longshore moving material. In addition, the coarser graded fill should provide a more stable beach.

Preface

The study summarized in this report was authorized by the Headquarters, US Army Corps of Engineers, and performed as part of the Civil Works Research and Development Work Unit 31232, Evaluation of Navigation and Shore Protection Structures. Mr. J. H. Lockhart, Jr., was Technical Monitor. Funds were provided through the Coastal Structures and Evaluation Branch (CS&E), Coastal Engineering Research Center (CERC), US Army Engineer Waterways Experiment Station (WES), Vicksburg, MS. Data presented in the report were collected by the Coastal Engineering Section of the US Army Engineer District, Buffalo (NCB).

Work was performed under the direct supervision of Ms. Pope, Chief, CS&E; Mr. Thomas W. Richardson, Chief, Engineering Development Division, CERC; Dr. C. Linwood Vincent, Program Manager, CERC; Mr. Charles C. Calhoun, Jr., Assistant Chief, CERC; and Dr. James R. Houston, Chief, CERC.

The report was prepared by Ms. Julie D. Rosati, Hydraulic Engineer, CS&E; Ms. Joan Pope, Research Physical Scientist, Chief, CS&E; Mr. Thomas Bender, Hydraulic Engineer, NCB; and Dr. Clifford L. Truitt, Research Hydraulic Engineer, CS&E. Dr. Truitt was Principal Investigator of the work unit. Mr. Darryl Bishop, Civil Engineering Technician, CS&E, provided drafting support for the figures in the report. This report was edited by Mr. Bobby Odom, Information Technology Laboratory, WES, under the Inter-Governmental Personnel Act.

COL Dwayne G. Lee, EN, was Commander and Director of WES during the preparation of this report. Dr. Robert W. Whalin was Technical Director.

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Conversion Factors, Non-SI to SI (Metric) Units of Measurement

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
acres	4,046.873	square metres
cubic yards	0.76545549	cubic metres
feet	0.3048	metres
inches	2.54	centimetres
miles (US statute)	1.609347	kilometres
square feet	0.09290304	square metres
tons (mass) per square foot	9,764.856	kilograms per square metre

THE LAKESHORE PARK, ASHTABULA, OHIO, BREAKWATER PROJECT

Introduction

1. Lakeshore Park, Ashtabula, OH, is a recreational area located on Lake Erie approximately 40 miles* southwest of Erie, PA, and about 50 miles northeast of Cleveland, OH (Figure 1 inset). The city park has existed since 1916 when the roads leading into the area and historical pavilion were constructed. Today the pavilion overlooks a small beach and boat launching area. Lakeshore Park is owned by the town of Ashtabula and consists of 50 acres of lakefront property with a 2,500-ft frontage on Lake Erie. As the clay bluffs

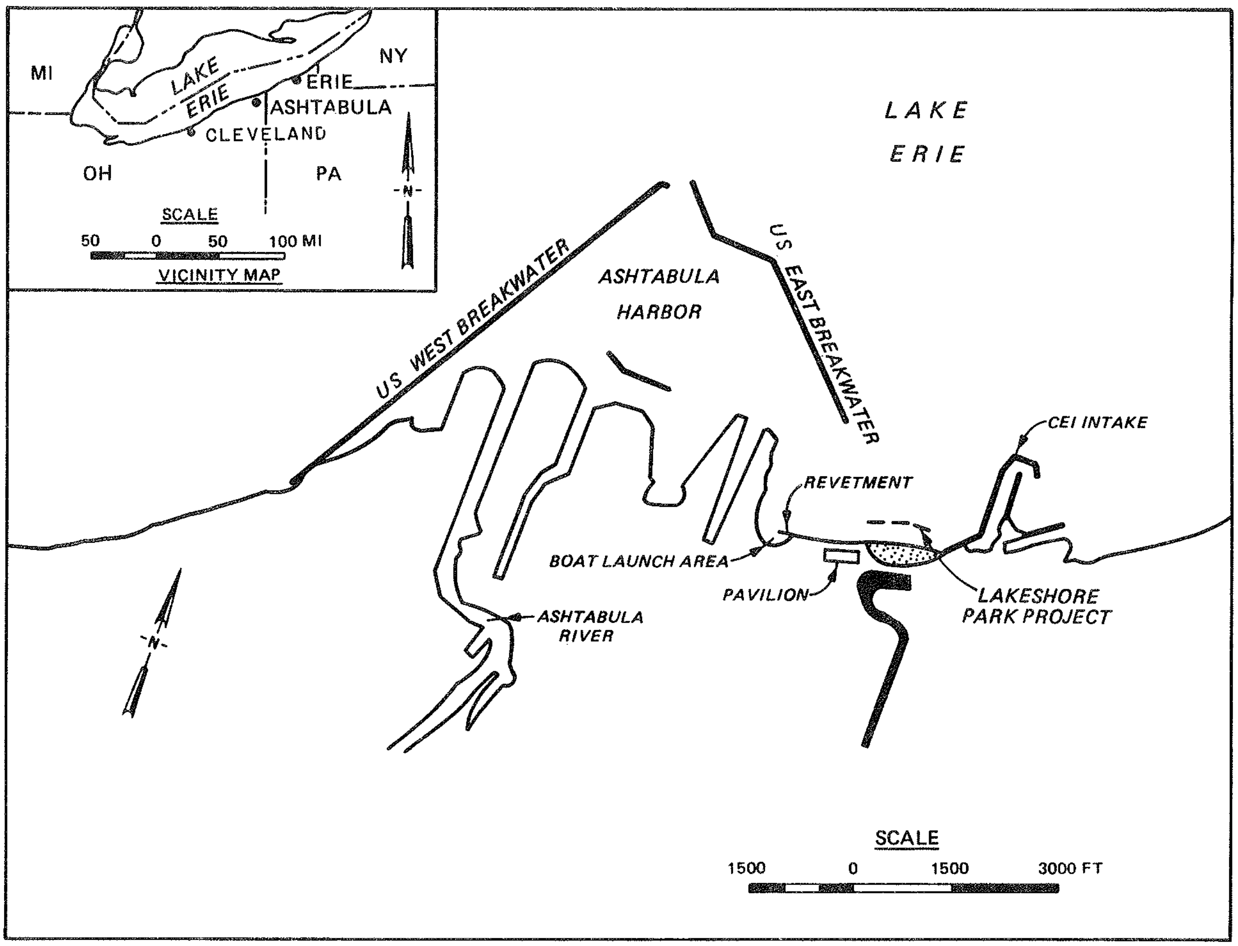

Figure 1. Project location in relationship to harbor structures and Ashtabula, OH, location map (inset) (after Bender 1984)

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 4.

(approximately 15 ft in height) composing the easternmost 800 ft of the park shoreline were persistently eroded, it was apparent that shore protection was necessary to prevent continued loss of park land.

2. In the fall of 1982, three rubble-mound segments of a detached breakwater system were constructed offshore of the clay bluffs, and 37,000 cu yd of sand with a mean grain size of 0.23 mm was placed on the eroding beach. The project was designed by the US Army Engineer District, Buffalo (NCB), under the authority of Section 103 of the 1962 River and Harbor Act. The Ashtabula Township Park Commission requested the project based on a need to restore the existing recreational beach area and to protect the shore against flooding and erosion by lake storms. Since completion of the project, beach fill has been lost from the project area more rapidly than was expected. By the fall of 1985, the beach fill had eroded to the degree that portions of the preproject bluff were exposed to wave attack.

3. A monitoring program consisting of bathymetric surveys, aerial photography, and Littoral Environment Observation (LEO) data was implemented in August 1984 by NCB and the US Army Engineer Waterways Experiment Station Coastal Engineering Research Center (CERC). The monitoring program was created in an effort to understand and document the reasons for the rapid loss rate of beach fill and general performance of the project. This report presents the results of that program, discusses the general coastal processes driving the beach response, and examines some recent modifications to the project area.

Project Description

4. Prior to project construction, the Lakeshore Park lakefront consisted of an 800-ft-long, 15-ft-wide beach area located in the easternmost region of the property. This small beach fronted clay bluffs approximately 15 ft in height. This area was adjacent on the west to a 1,500-ft rubble-mound revetment fronting the pavilion area, built in 1977 to reduce flooding of the pavilion. The revetment covers a deteriorated seawall that had been built in the 1930's to protect the pavilion from flooding during lake storms. The westernmost section of the park's lakefront consists of two boat ramps. The Cleveland Electric Illuminating Company (CEI) intake structure, immediately east of the park, and the US East Breakwater, west of the park,

effectively block wave energy approaching the shore at oblique angles (Figure 1).

5. The erosion problem at Lakeshore Park became acute as high lake levels in conjunction with storms continually eroded the easternmost 800 ft of park property. Because these bluffs are composed of fine clay-sized material with very little sand or gravel, erosion of the bluffs released little littoral material to the beach. The estimated recession rate along the park bluffs from 1948 to 1973 was 1.6 ft/year. Comparison of aerial photographs indicated a recession rate of 2.2 ft/year between 1968 and 1973 and 2.4 ft/year between 1973 and 1978 (US Army Engineer District, Buffalo, 1982).

6. Five objectives were formulated to assist in the assessment of various alternative shore protection plans for the design life of the project from 1982 to 2032. These objectives were to: (a) eliminate shoreline erosion along the 800 ft of erodible bluffs preventing further upland damages at Lakeshore Park; (b) restore a recreational beach along the east lakefront area in order to contribute to the land- and water-based recreation resources at Lakeshore Park for swimming, fishing, picnicking, boating, and camping; (c) contribute to the reduction of flooding along the central lakefront area for protection of property; (d) contribute to the ecological value of Lakeshore Park habitat in terms of diversity, wildlife, erosion control, and aesthetics; and (e) contribute to the preservation and/or enhancement of the natural and scenic view of Lake Erie.

Design of the Project

7. Ten alternative plans, including the "no-action" plan, were assessed on their ability to reduce flooding and beach erosion and to provide a recreational beach. The alternatives basically involved various sizes, types, and locations of breakwater structures in combination with beach fill, beach fill in combination with a groin, and beach fill alone. The alternatives using beach fill alone were eliminated because of an estimated high offshore loss rate of 18,000 cu yd/year (US Army Engineer District, Buffalo, 1982). The beach-fill alternatives would require costly annual renourishment and provide an uncertain beach area. Because the harbor structures appear to shelter the beach from high angled waves, it was felt by the designers that significant sediment transport only occurred in the onshore/offshore direction. Following

this reasoning, the groin with beach-fill alternative was eliminated because groins are designed to intercept the longshore component of sediment transport. The no-action plan was considered along with each option in order to compare the cost of each design with the possible economic loss of the park facilities.

8. The most economical plan that optimized the stated objectives and had the most favorable benefit-to-cost ratio consisted of a three-segment rubble-mound breakwater system and 37,000 cu yd of beach fill placed along the 800 ft of eroding beach. Each breakwater segment was 125 ft in length with 200-ft gaps between segments, therefore, fronting a shoreline length of 775 ft. The structures were built between the -3 and -4 ft contour (Low Water Datum (LWD)), approximately 250 ft offshore from the restored beach. The structures were built of stone ranging from 1.0 to 2.5 tons. The height of the structures was +6.5 ft LWD with a crest width of 8.5 ft. The transmissibility of the structures, i.e., the portion of the wave energy that could pass through a breakwater segment, was estimated to be approximately 50 percent based on stone size and cross-sectional design.

9. The design grain size for the proposed beach fill ranged from 0.3 to 1.3 mm. However, the as-built median diameter of fill was 0.23 mm. The design crest height of the beach fill (+8.0 ft LWD) was based on the maximum wave runup for the 10-year design wave (deepwater wave height of 9.3 ft) in conjunction with the 20-year design water level (+6.5 ft LWD). Annual losses of beach fill were expected to be approximately 10 percent of the initial 37,000 cu yd placed or 3,700 cu yd/year. A permanent access road to the beach from the top of the bluff would be built to allow initial placement of the beach fill and periodic renourishment. The as-built project configuration is presented in Figure 2.

10. The intent of the project was for the breakwater system to protect and retain the beach. Sufficient wave energy would reach the shoreline by transmission through the structures and gaps to prevent tombolo development and allow littoral processes to continue in the lee of the structures. The project was designed by constructing diffraction diagrams between and around the breakwaters using a wave with 5-sec period, the most representative wave period that would occur at the site (US Army Engineer District, Buffalo, 1982). The intersections of diffraction coefficient isolines equal to 0.3 through the breakwater gaps were used as indicators of the shoreward terminus

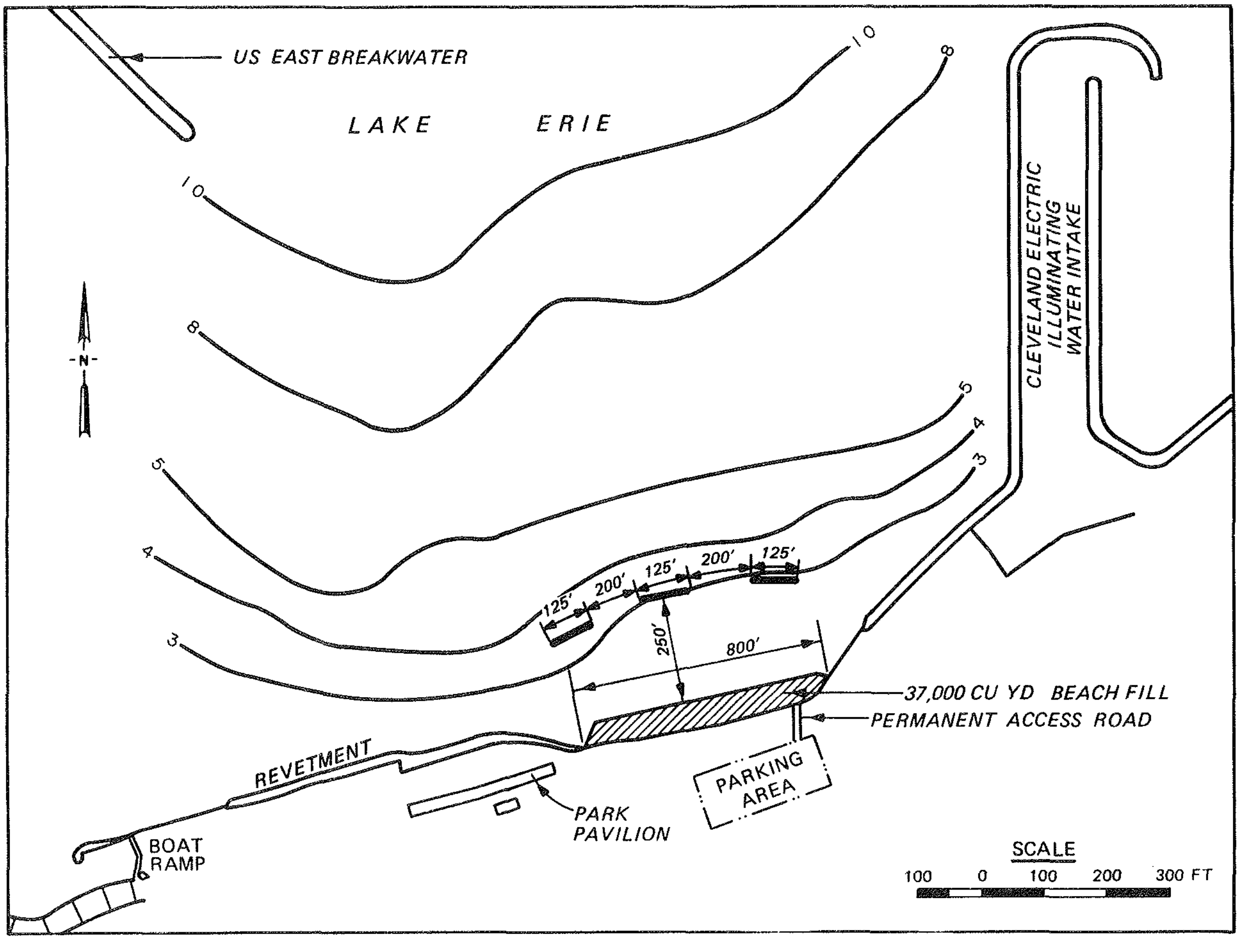


Figure 2. Lakeshore Park project as-built configuration (US Army Engineer District, Buffalo, 1982)

of the beach. The dimensions of two other segmented detached breakwater projects on Lake Erie--Presque Isle, Erie, PA, and Lakeview Park, Lorain, OH--were also used as guidelines in designing the Lakeshore Park project.

Data Analysis

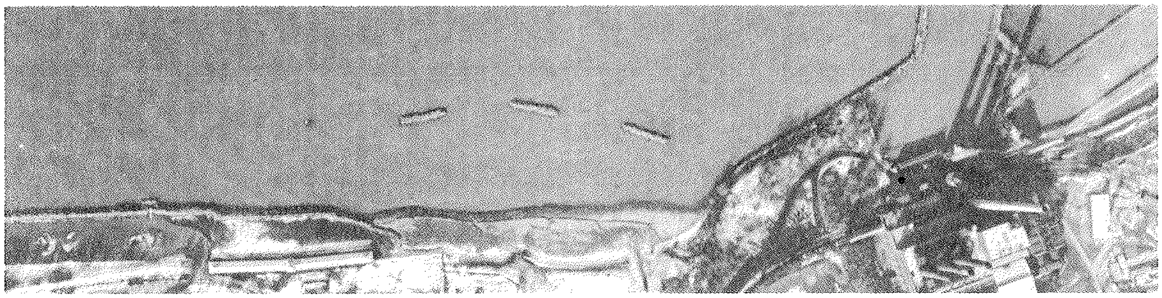
11. Since completion of the project, the beach area has experienced rapid losses of the placed fill. Initially, it was speculated that the placed material was being moved to the immediate offshore area as it adjusted to an equilibrium profile shape. Approximately 1 year after project construction, however, the boat launching area at the western end of the park had shoaled to such an extent that it needed to be dredged (Bender 1984). This led to the speculation that at least a portion of the placed fill was being moved in a westerly direction along the rubble-mound revetment and was being deposited

into the small boat launching area. Approximately 900 cu yd of material was dredged from the launching area in May-June 1983 and 1,000 cu yd in June 1984; the dredged material was placed on the project beach. The material dredged from the launching area was good quality, fine-grained sand with median grain size of 0.36 mm. The relative coarseness of the dredged material (d_{50} = 0.36 mm) compared with the original beach fill (d_{50} = 0.23 mm) indicates that the finer portion of the original material was not transported to the boat launch area. The NCB and CERC initiated a monitoring program in 1984 to document and evaluate the reasons for the rapid loss rate of beach fill. A data base was created consisting of four controlled aerial photographs, five bathymetric surveys, and a 4-month data set from four LEO stations. The LEO program consists of visually estimated wave heights, wave periods, wave directions, longshore current speeds, beach slopes, and wind speeds usually observed daily in a standard format (Schneider 1980).

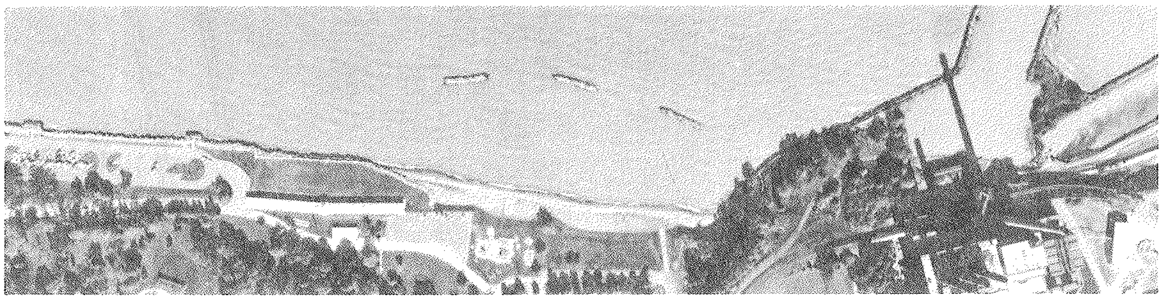
Aerial photography

12. Controlled aerial photographs at a scale of 1:4800 were included in the monitoring program to provide a qualitative history of the project shoreline evolution. These photos were taken in December 1982, October 1984, November 1984, and July 1985 and are presented in Figure 3 along with the mean lake level on the day of the aerial photographs. Immediately after construction (aerial photograph, December 1982), there was a very slight sinuosity of the beach planform, indicating some influence of the breakwater on the beach. However, as the beach eroded, the shoreline response in later photographs becomes negligible. All the aerial photographs except for July 1985 indicate some reflection of incoming waves off the CEI intake structure.

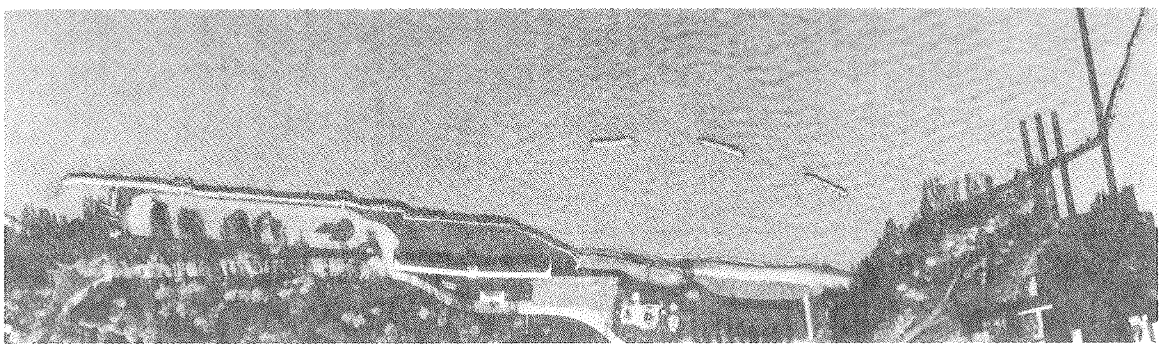
13. In order to relate the shoreline changes to a fixed reference, the shorelines from these aerial photographs were digitized and drawn on the same plot (Figure 4). These shorelines have not been corrected for the mean daily lake level, which was generally increasing with each successive aerial photograph. From Figure 4, the continuous retreat of the shoreline is obvious. Between October and November 1984, there is a slight rotation of the shoreline about a point near the center of the beach. This most likely represents a short-term shift in wave direction from the northeast to the northwest. Such short-term reorientations of the shoreline angle within a pocket beach are not unusual. However, this rotation does indicate that the beach was very responsive to the variability in the wave climate despite the protection of the



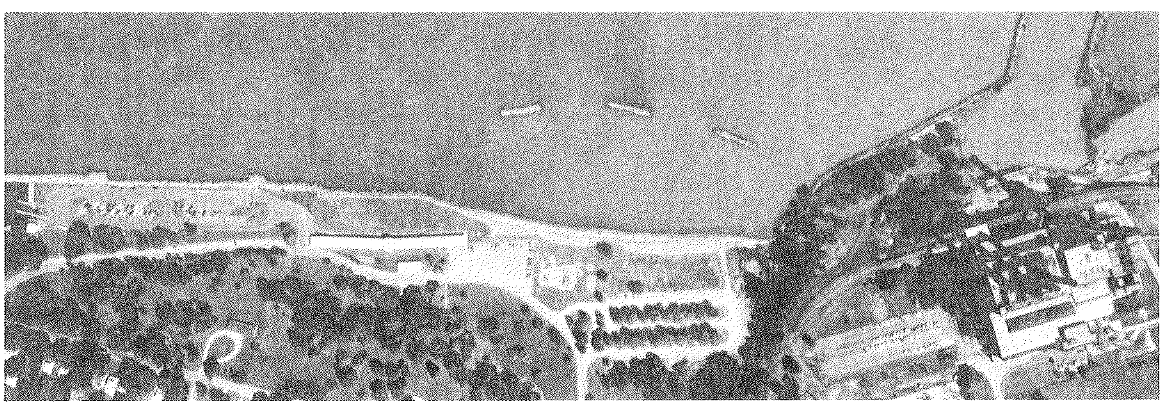
a. 14 December 1982, mean daily lake level = 570.86 ft LWD



b. 2 October 1984, mean daily lake level = 571.84 ft LWD



c. 14 November 1984, mean daily lake level = 571.53 ft LWD



d. 24 July 1985, mean daily lake level = 572.93 ft LWD

Figure 3. Lakeshore Park controlled aerial photographs

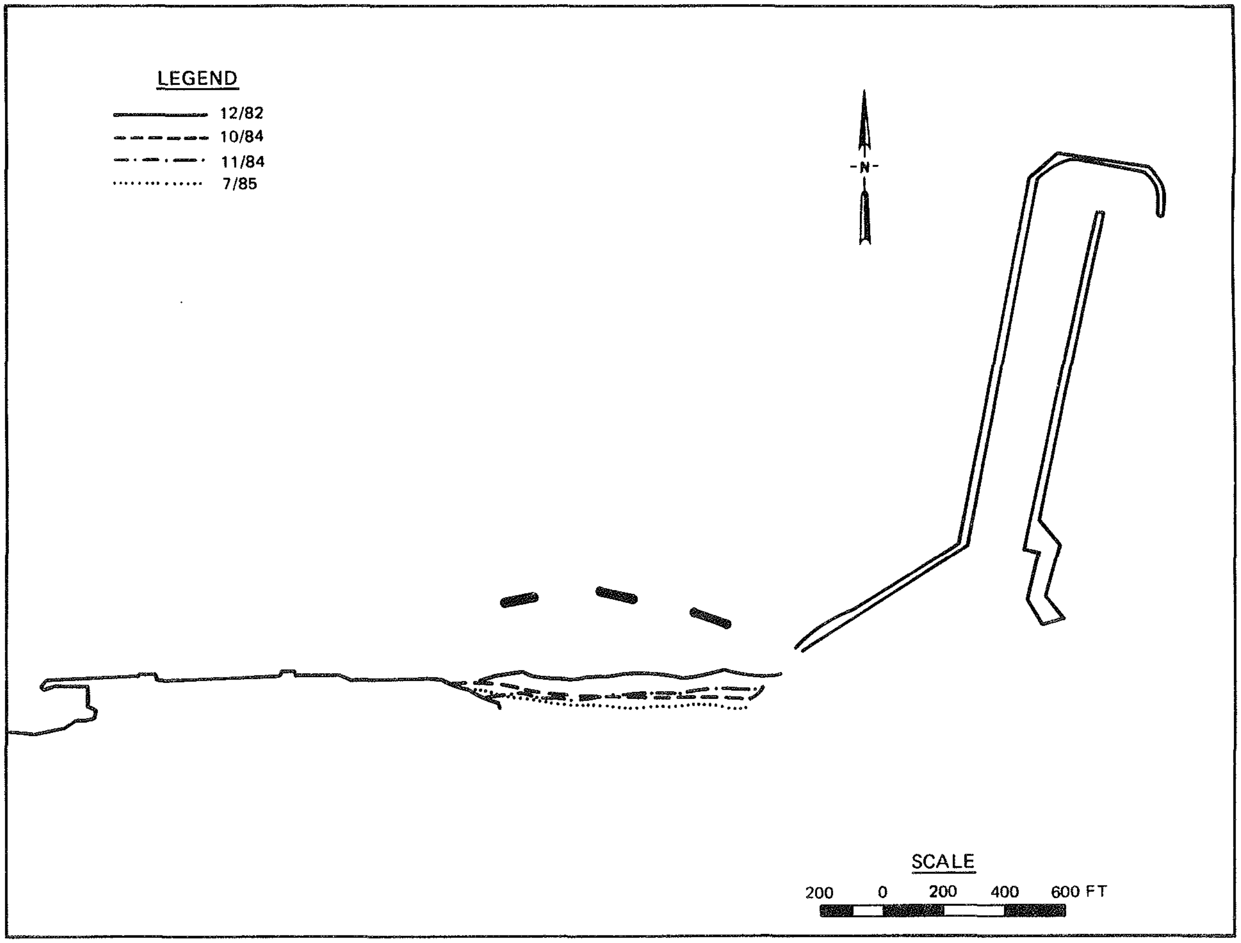


Figure 4. Lakeshore Park aerial shorelines (includes effects of lake levels)

breakwaters. The most recent shoreline position, July 1985, shows the furthest retreat of the shoreline for the aerial photograph data set.

Bathymetry data

14. Six sets of bathymetric and topographic surveys conducted during September 1978, September 1979, June 1983, September 1984, December 1984, and August 1985 were digitized, and contour plots were drawn (Figures 5-10, respectively) using CPS-1, a contour plotting software package (Copyright 1979, Radian Corporation). Contour plots of change between time periods were generated (Figures 11-15), and volumes of change were calculated between each time period. Using these volume change data, the loss of the beach fill can be quantified. Table 1 presents the results of the volume change analysis reported for six regions of the project area as shown in Figure 16. The term "net change" indicates the quantity of material remaining in a polygon when

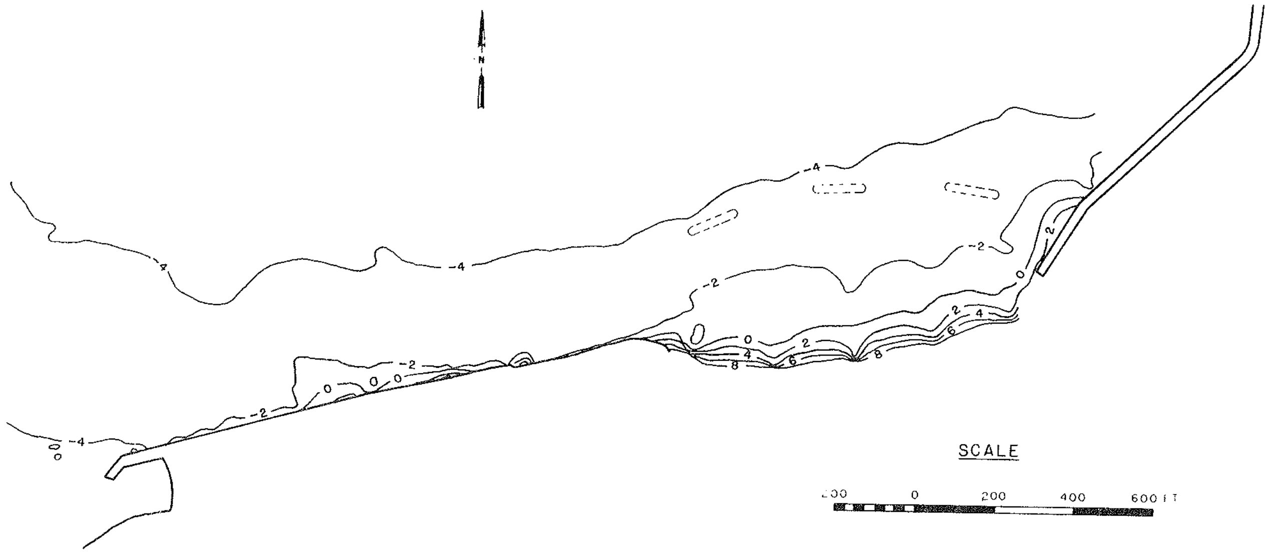


Figure 5. September 1978 contour plot (feet relative to LWD)

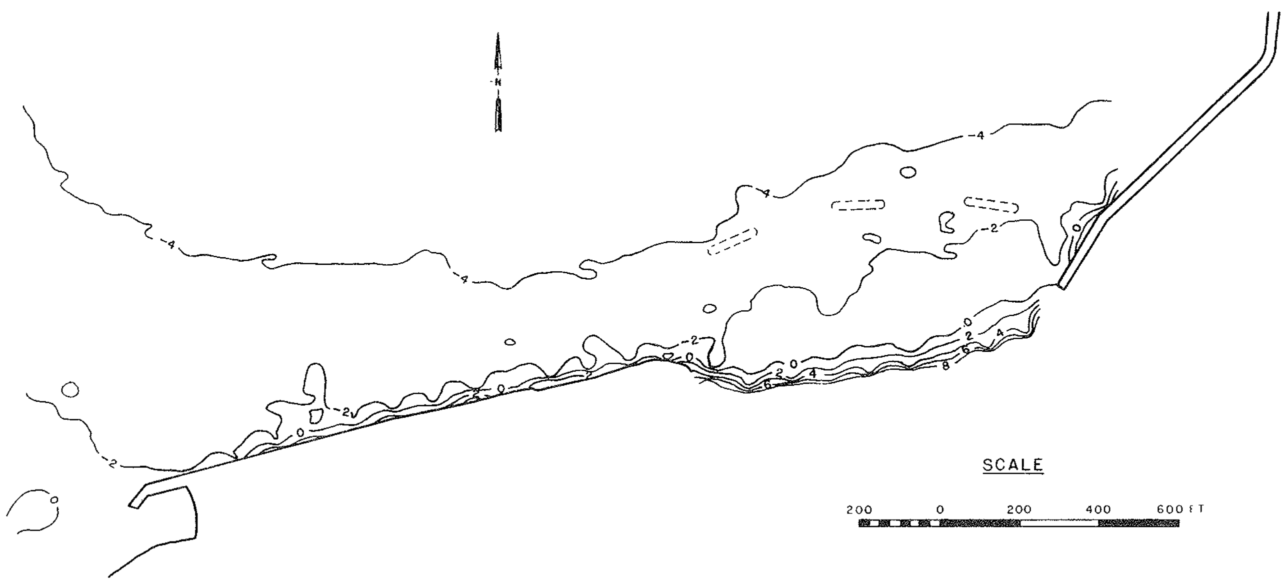


Figure 6. September 1979 contour plot (feet relative to LWD)

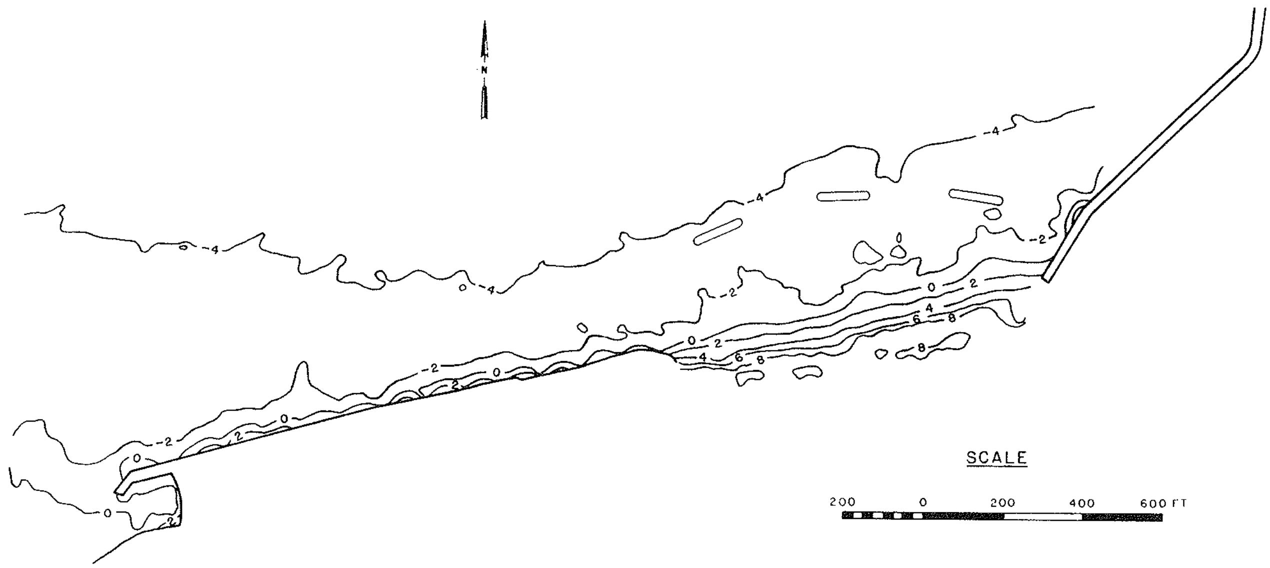


Figure 7. June 1983 contour plot (feet relative to LWD)

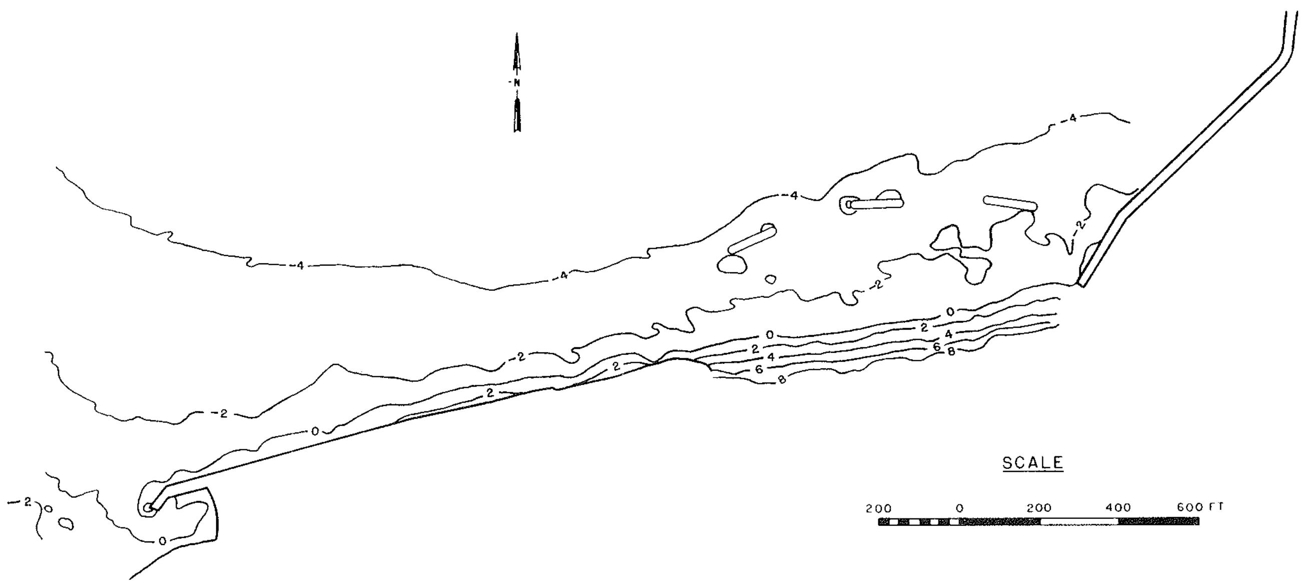


Figure 8. September 1984 contour plot (feet relative to LWD)

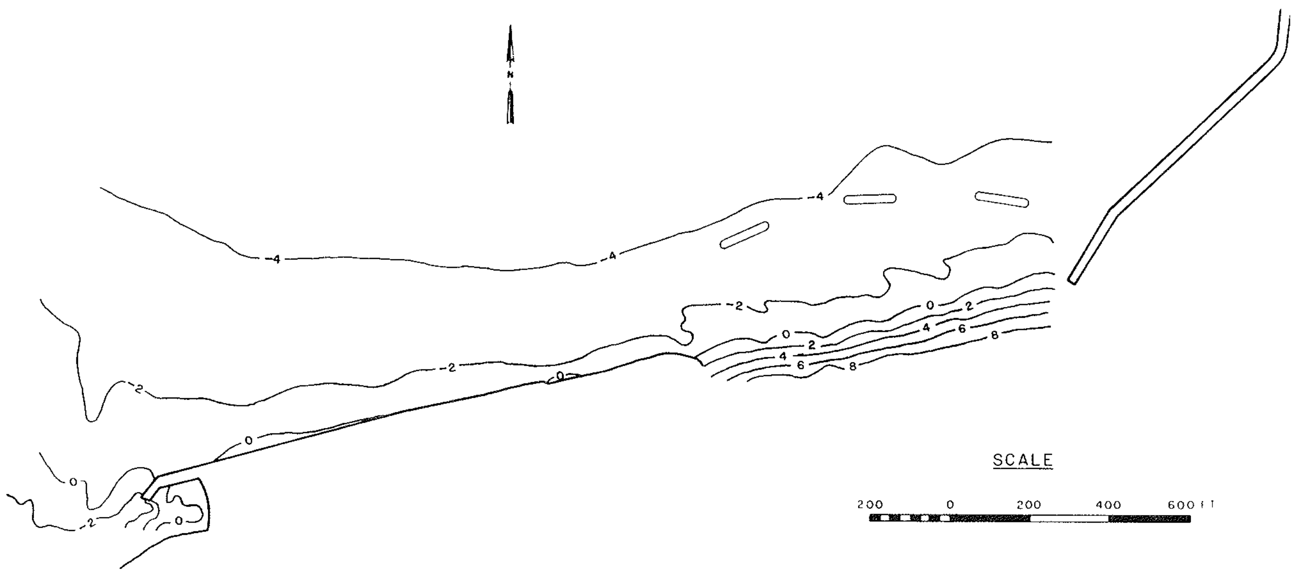


Figure 9. December 1984 contour plot (feet relative to LWD)

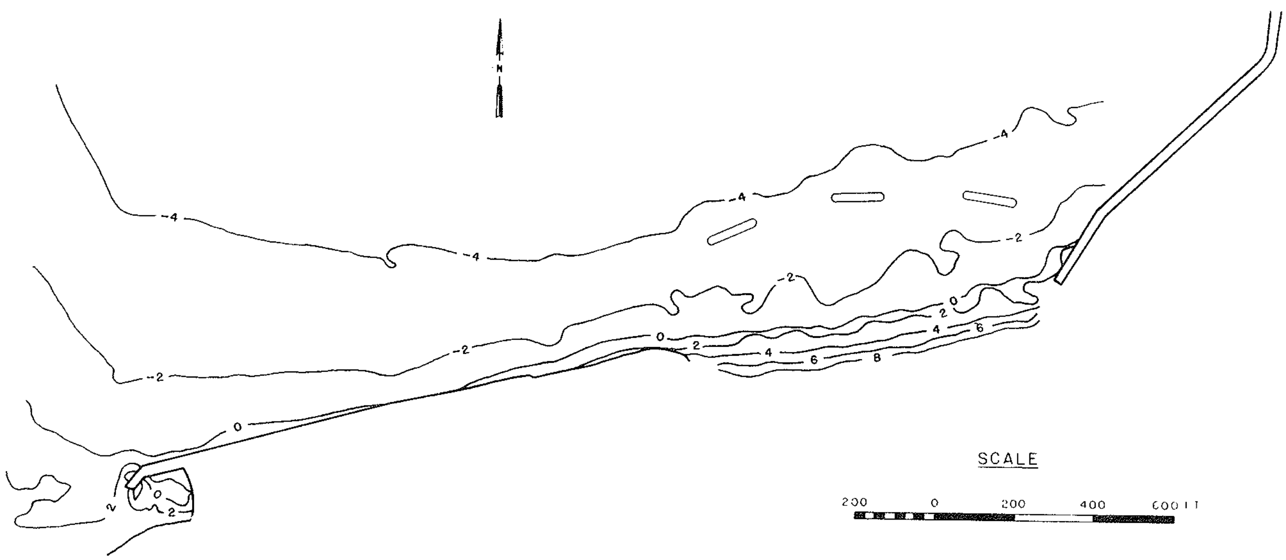


Figure 10. August 1985 contour plot (feet relative to LWD)

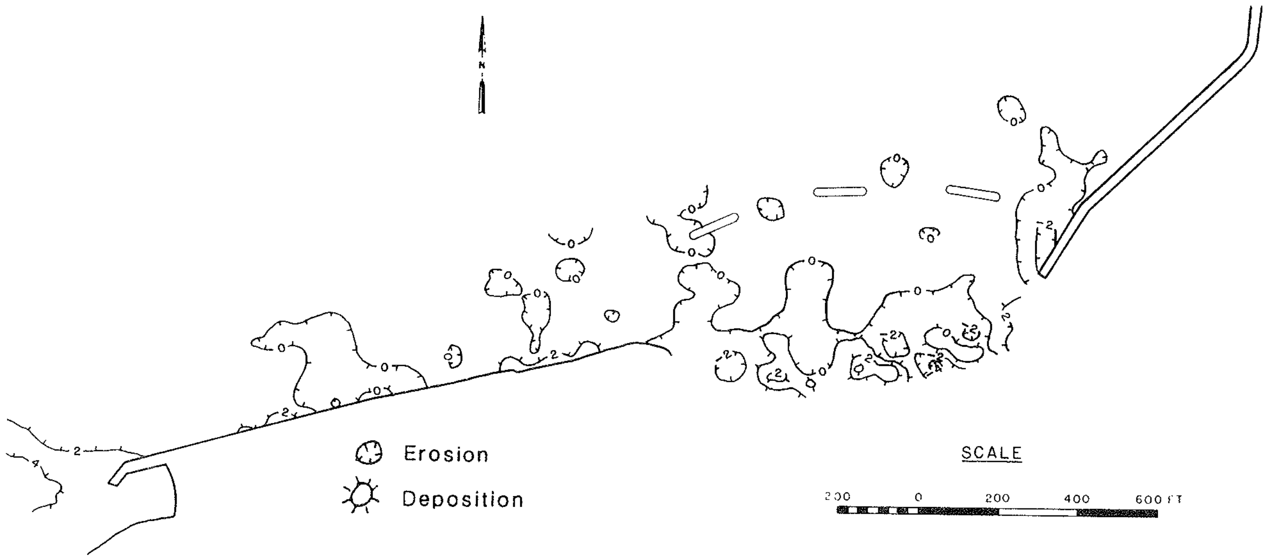


Figure 11. Contour plot of change between September 1978 and September 1979 (feet)

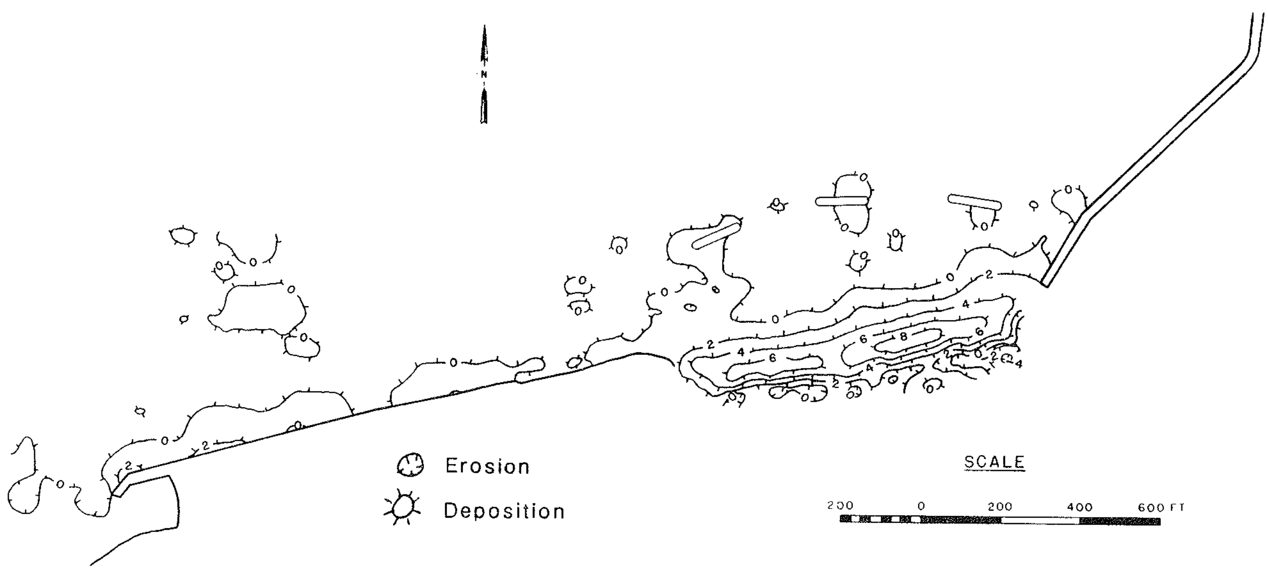


Figure 12. Contour plot of change between September 1979 and June 1983 (feet)

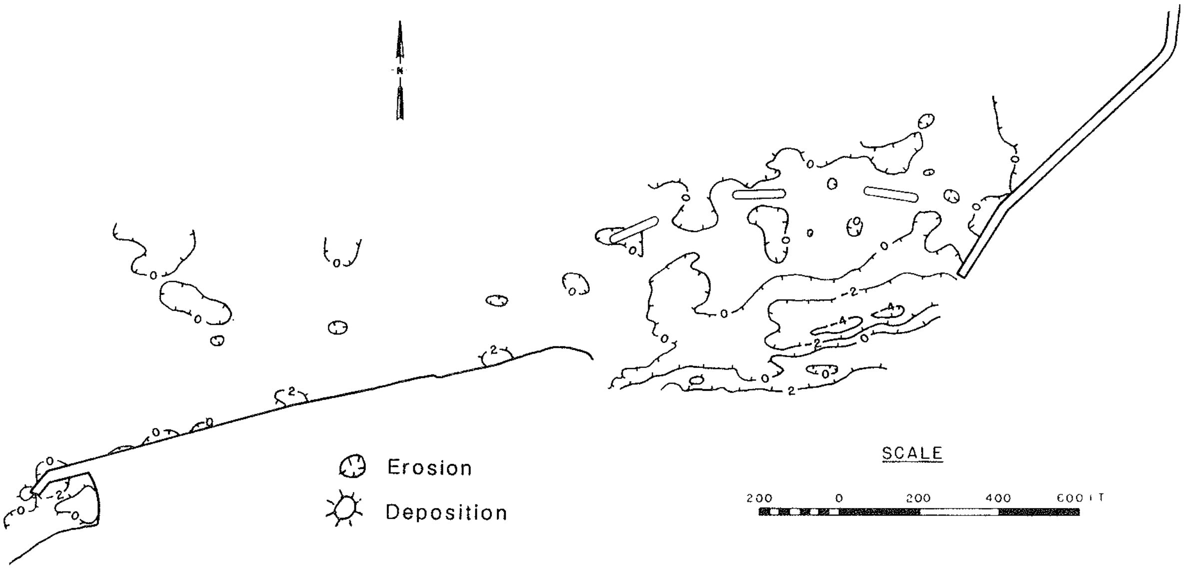


Figure 13. Contour plot of change between June 1983 and September 1984 (feet)

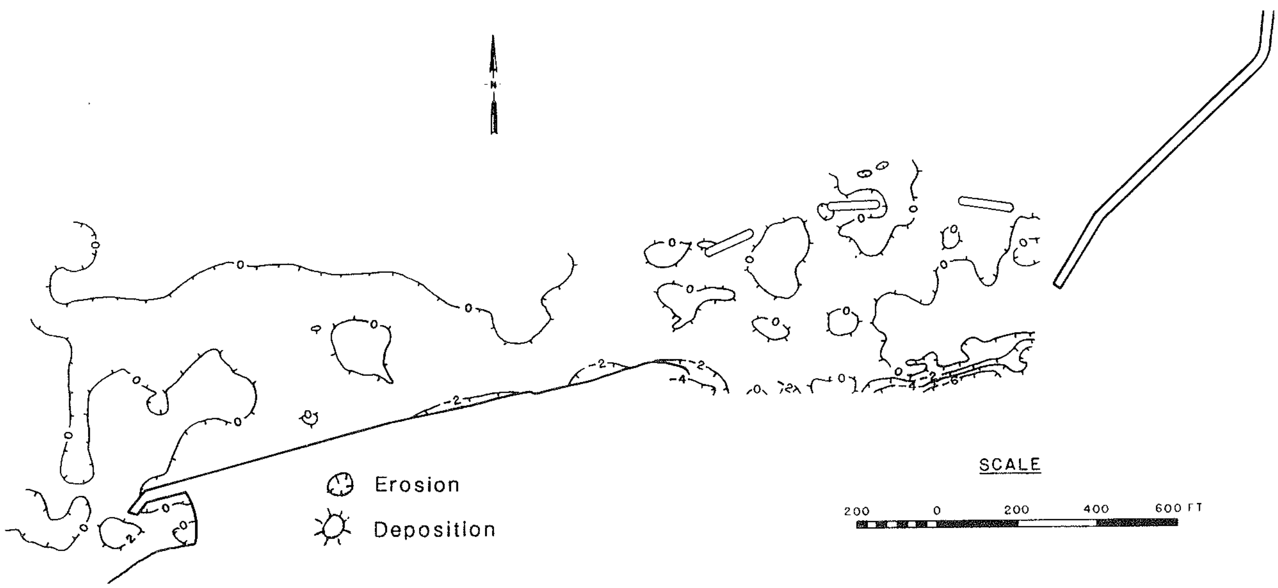


Figure 14. Contour plot of change between September 1984 and December 1984 (feet)

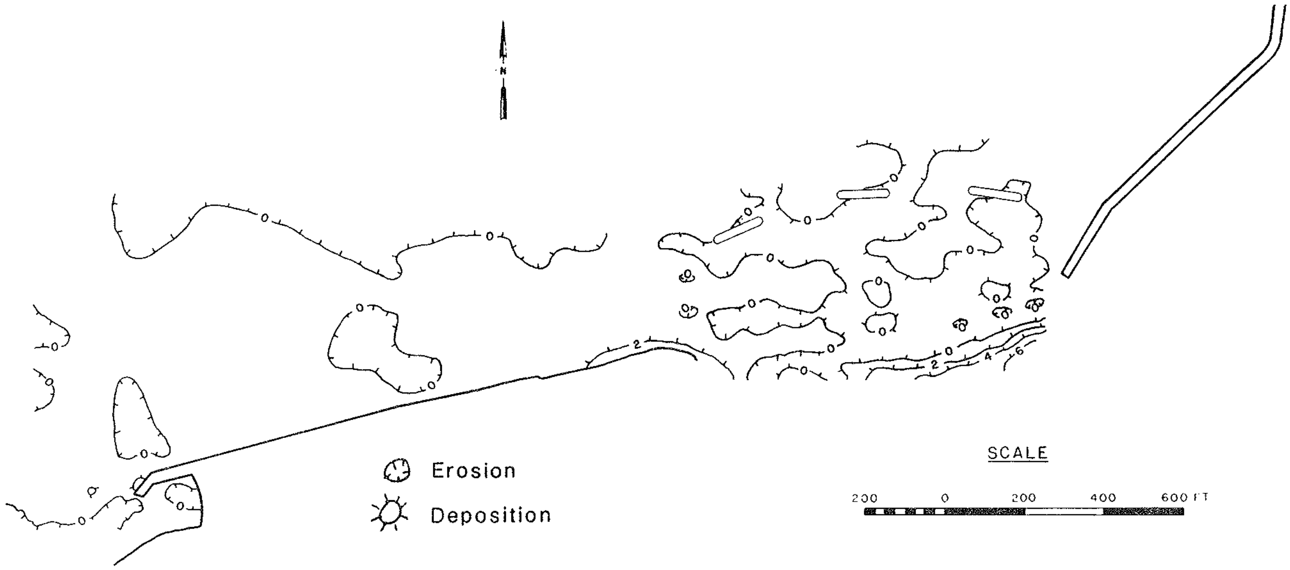


Figure 15. Contour plot of change between December 1984 and August 1985 (feet)

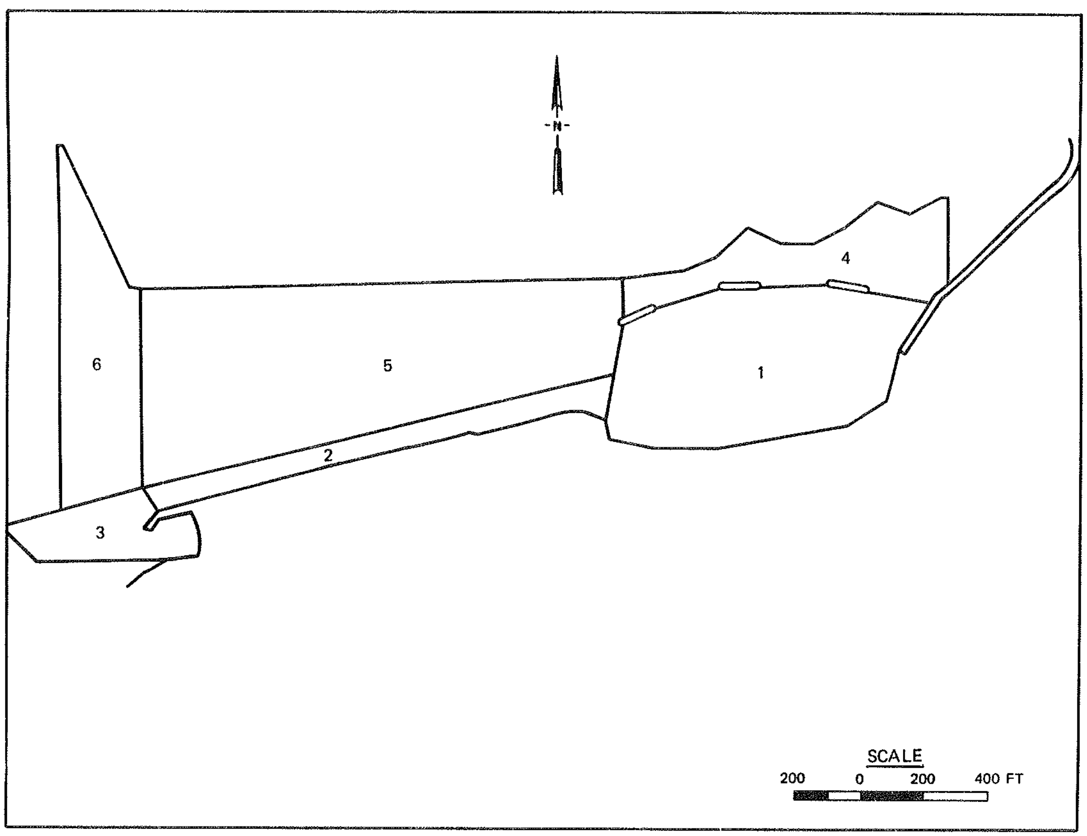


Figure 16. Definition of regions used in volume change analysis

adjusted for material added or subtracted from the region. "Fill" accounts for beach fill added to a polygon during a time period, and "dredge" accounts for dredged material added or subtracted from a region during a time period.

15. From September 1979 to June 1983, a net volume change of -16,252 cu yd is indicated for Region 1 (lee of breakwater), indicating at first glance that a large portion of the initial beach fill was lost from Region 1 within 9 months of placement. However, there are three possible explanations for this volume change: (a) erosion occurred between September 1979 and the time the beach fill was placed (September 1982); (b) the volume of material placed was not the entire 37,000 cu yd; or (c) the initial loss adjustment of beach fill was extremely high. Because there is every indication that the entire 37,000 cu yd was initially placed, and it is unlikely that such severe erosion occurred between September 1979 and the time the beach fill was placed, it will be assumed that the net volume change during the period represents an initial loss/adjustment of the beach fill. Region 1 continued to lose material during the rest of the time periods, except for one accretionary period from December 1984 to August 1985 (possibly a seasonal accretion).

16. In Region 2 (offshore of rubble-mound structure), there are three postconstruction accretionary periods and one erosional period from September to December 1984. The accretion most likely represents beach material moving in from Region 1, and the period of erosion may represent some seasonality of the wave conditions or some error in the bathymetry data. Unfortunately, data are unavailable for Region 3 for the first two time periods; however, 900 cu yd of material was dredged from the area from May to June 1983, indicating that the region was shoaling during this time period. The rest of the time periods indicates a continual increase in volume through time. In June 1984, 1,000 cu yd of material was dredged from the boat launch area, and this material was placed on the beach. Region 4 (offshore of breakwater) had a slight net volume decrease from September 1979 to August 1985 although there were accretional and erosional variations of the same magnitudes during other time periods.

17. From September 1978 to September 1979, there were large volume increases in Region 2 (offshore of the revetment), Region 5 (offshore of the rubble-mound structure), and Region 6 (offshore of the boat launch area). These volume changes were on the order of a 4- to 10-in. increase over the

entire area. This increase is extremely unlikely because material of that quantity had not been added to the system during that period. Much of the subaqueous area in these regions consists of exposed bedrock. Error in the September 1979 data set is suspected as the cause of this incongruity. In several other data periods, large volume changes also occurred in Regions 5 and 6. Some error either in the survey process for these offshore areas or reduction of the survey data is suspected. The volume changes between consecutive time periods for Regions 5 and 6 have been ignored in the rest of the data analysis. However, the total volume change from September 1979 to August 1985 for Regions 5 and 6 appears reasonable.

18. In order to remove any seasonal changes and possible error in the September 1979 survey, the data for Regions 1-4 were grouped into time spans that generally begin and end in the summer months: September 1978 to June 1983, June 1983 to September 1984, and September 1984 to August 1985. The volume changes for Regions 1, 2, 3, and 4 for these time periods are presented in Figure 17.

September 1978 to June 1983

19. From the September 1978 to June 1983 time period, Region 1 lost a large quantity of the initially placed beach fill. There is also an increase in Region 2, suggesting that the fill moved from the beach area to the offshore revetment area. During this time period, 900 cu yd was dredged from the boat launch area (Region 3) and placed on the beach (Region 1). There was a minor loss of material in Region 4 during this time period.

June 1983 to September 1984

20. The second time period (June 1983 to September 1984) shows a loss of material in Region 1 and an increase of material in Regions 2 and 3. During this period, 1,000 cu yd was dredged from Region 3, and this material was placed on the beach (Region 1). Region 4 gained a slight volume of material during this period. The loss in Region 1 is entirely accounted for by the gains in Regions 2, 3, and 4.

September 1984 to August 1985

21. From September 1984 to August 1985, Regions 1, 2, and 4 lost material while Region 3 gained material. The gain in Region 3 accounts for only 72 percent of the material lost from Regions 1, 2, and 4. Most likely the remainder of the material was lost to the offshore regions.

22. It appears that material was initially lost from Region 1 moving

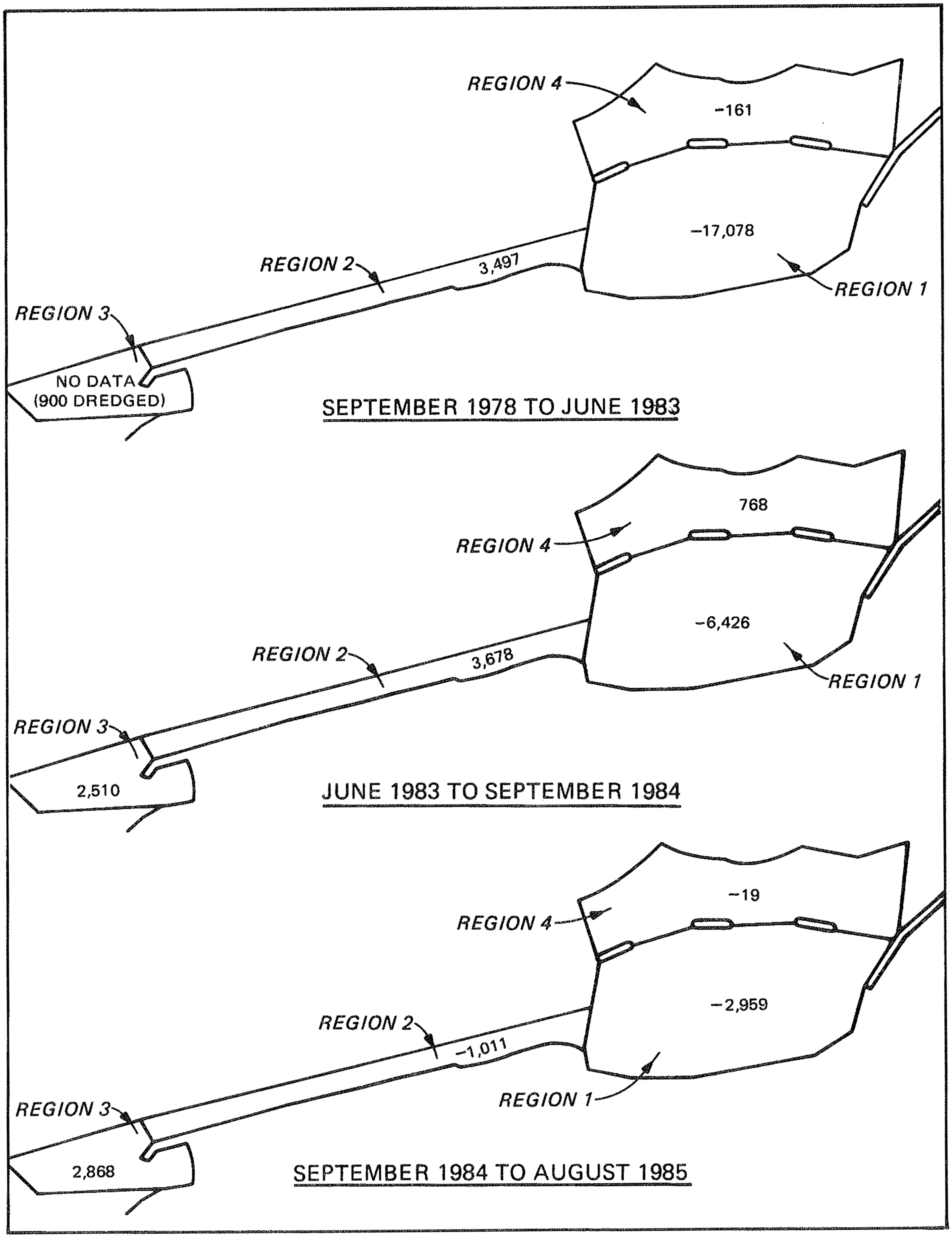


Figure 17. Volume changes in cubic yards for Regions 1-4

into Region 2 (and possibly Region 3). Eventually Region 2 began losing material as Region 1, which was supplying the system with littoral material, reached an equilibrium condition. Because the gains and losses in volumes are nearly equal for Regions 1, 2, 3, and 4 for the last two time periods, it appears as if these regions form a near-complete littoral cell.

23. The total volume change from September 1979 to August 1985 for Region 1 indicates that approximately 30 percent of the 37,000 cu yd of placed material remained as of August 1985. Of the quantity that was lost, 60 percent of it can be accounted for the Regions 2-6. Region 2 (boat launch area) received the majority of this material, approximately 25 percent of the quantity lost from Region 1.

LEO data

24. LEO data were collected from 1 August to 1 December 1985 at four locations at Lakeshore Park. Using the observed wave height, period, and direction data, magnitudes and directions of longshore sediment transport were calculated using Equations 4-38 and 4-50b from the Shore Protection Manual (1984) at each station (Figure 18). All four stations indicate transport from

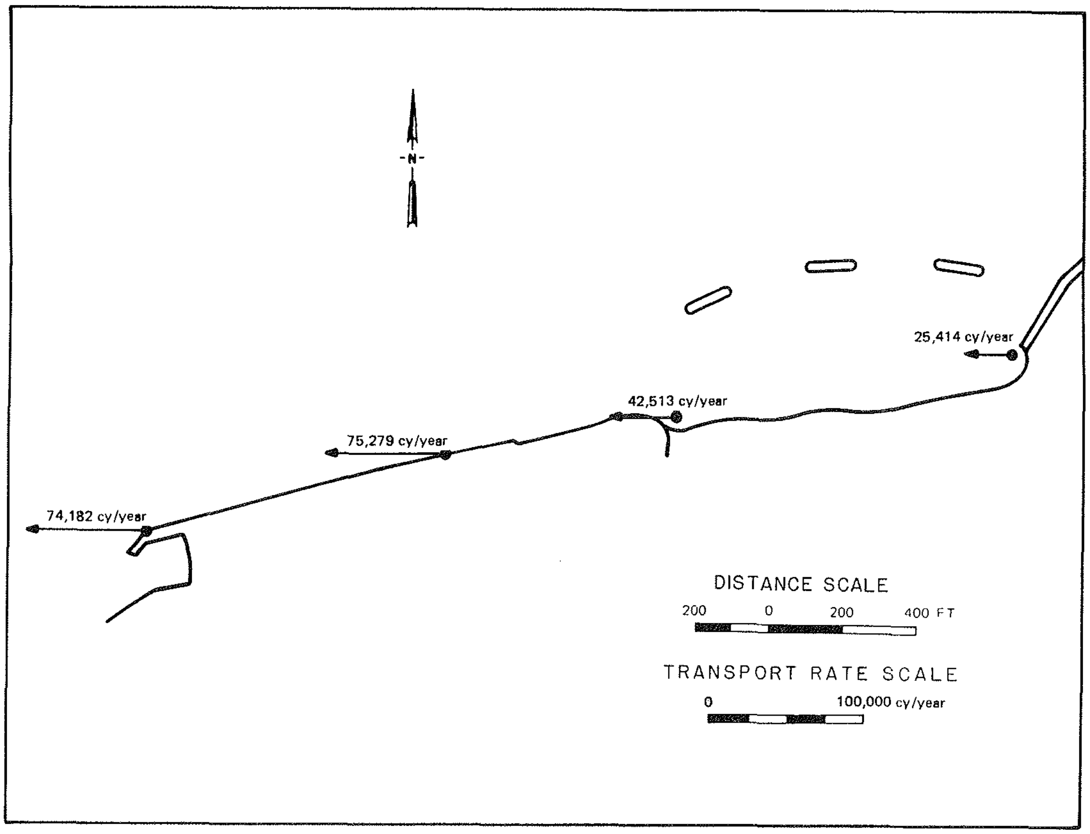


Figure 18. Magnitude and direction of sediment transport from LEO data August-December 1985

east to west for this limited period, with the magnitude of potential net transport increasing from approximately 25,000 cu yd/year at the easternmost station to approximately 75,000 cu yd/ year at the two westernmost stations. Gross sediment transport rates are nearly equal to the net transport rates, increasing from approximately 26,000 cu yd/year at the easternmost station to approximately 75,000 cu yd/ year at the two westernmost stations. The near-equality between net and gross sediment transport rates indicates that transport from west to east was negligible during this time period. Although the data set only represents a wave climate from 1 August to 1 December during one particular year, there is a strong indication of westerly transport of material. Perhaps the westerly currents are contributed to by waves reflected off the CEI intake structure or eddies around harbor structures. The predicted LEO transport rates are an order of magnitude greater than the volume changes calculated; the LEO data are probably most useful in a qualitative sense, indicating directions of transport and relative trends between stations.

Recent Modifications to the Lakeshore Park Project

25. In August 1986, NCB built a groin at the western end of the beach area in an effort to hold some of the westerly moving material in the beach area. The groin was determined to be the least costly method of reducing sand losses to the west and would pay for itself in reduced renourishment costs in 6 months. The groin is only 150 ft in length, reflecting the assumption that most of the transport is occurring in the nearshore zone. Stone left over from building the west groin was used to build a second groin at the east end of the beach, approximately 50 ft in length. In December 1986, approximately 2,300 cu yd of material with a median grain size of 2.4 mm was placed on the back bluff area to help prevent further erosion of the bluff during winter storms. In May 1987, the material previously placed on the back bluff area was spread onto the beach, and approximately 2,500 cu yd of the 2.4 mm median grain size material was also placed on the beach. The coarser material is expected to be significantly more stable than the original fill. Plans call for 1,000 cu yd from dredging of the boat launch area to be placed on the beach in the summer of 1987. An aerial photograph taken in the spring of 1987 shows the locations of the two groins and the initial beach response to the structures (Figure 19). A site inspection in August 1987 indicated that both

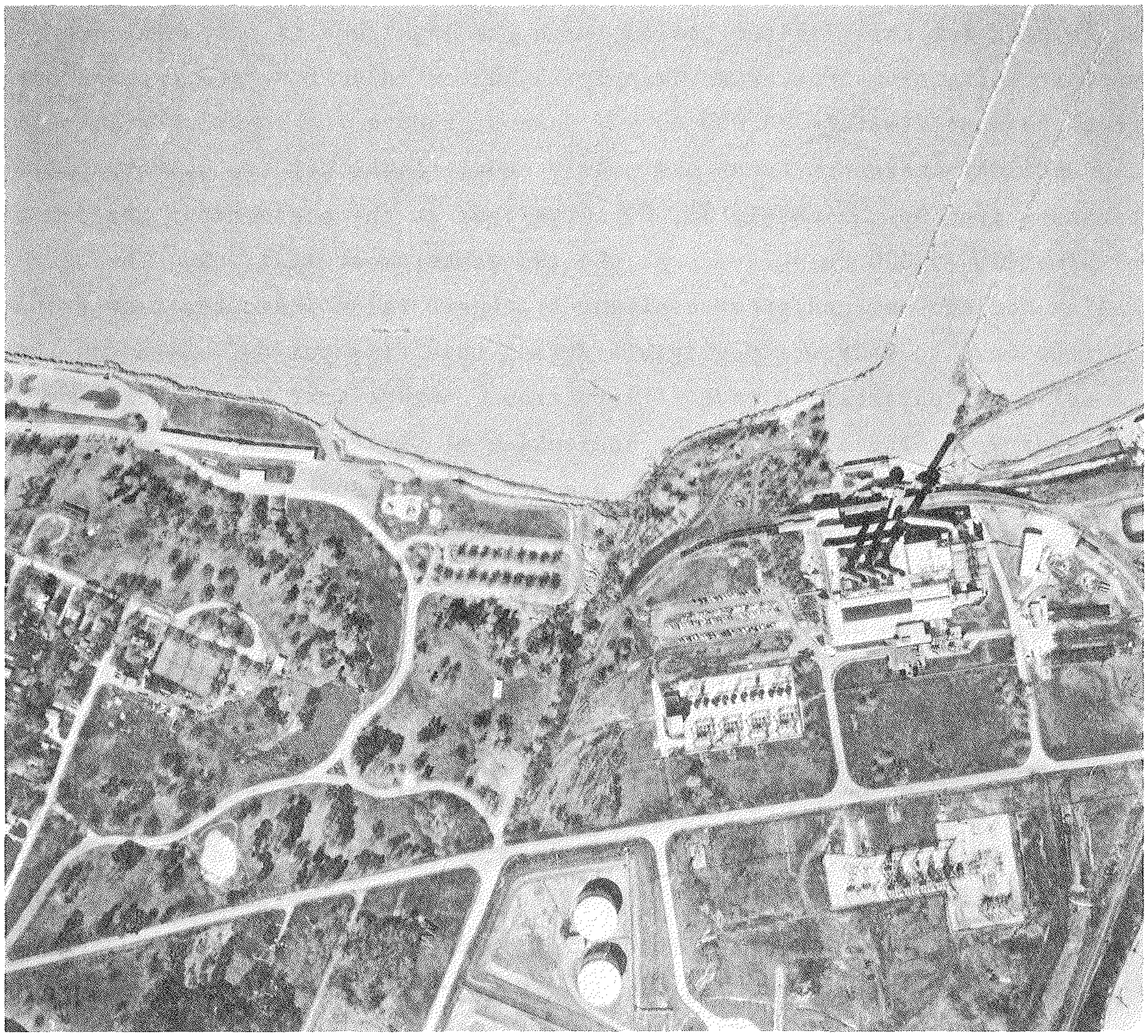


Figure 19. April 1987 controlled aerial photograph showing locations of two groins (scale 1:4800)

groins are somewhat permeable. However, the western groin does appear to be effective in trapping westward-moving material.

Discussion

26. The reason for the rapid loss of beach fill in the project area could be one or a combination of the following: (a) small grain size and poor quality of initial beach fill; (b) lack of sufficient annual beach nourishment; (c) recent record-high lake levels, and/or (d) an inadequate protection of the beach area by the segmented breakwater. The median grain size of the placed material was 0.23 mm while design range for the median grain size was

0.3 to 1.3 mm. The placed material was also of poor quality, 15 percent silts and fines that most likely were washed offshore and lost to the system. Although beach nourishment was planned on an annual basis in the design of the project, the initial nourishment events were limited to the quantities of material dredged from the boat launch area. The Lake Erie water levels have been increasing since construction of the project, and the average yearly water level for 1986 reached 573.19 ft LWD, exceeding the design water level by approximately 0.1 ft (US Department of Commerce, National Oceanic and Atmospheric Association, and National Ocean Service 1979-1987). The record-setting high lake levels were not predicted in the design period and are certainly a factor in erosion of the beach.

27. Table 2 compares the breakwater parameters of Lakeshore Park with two other Lake Erie breakwater projects which have been successful in protecting the beach. The Lakeshore Park breakwater has the largest X/ds parameter of the projects presented in Table 2, suggesting that the Lakeshore Park structures may have been built too far offshore. The Lakeshore Park structures also have a low crest elevation. Structures with longer length segments and/or closer to the shore would provide more protection to the beach area. Segments closer together, i.e., with smaller gap distance, would allow less wave energy to reach the shoreline. Adding more stone to the segments to decrease the gap width or to increase the crest elevation may be viable alternatives that would provide additional protection to the project beach. However, it is likely that the west groin will reduce erosion of the project beach.

Summary and Conclusions

28. The lack of littoral material and recent high lake levels at Lakeshore Park contributed to chronic erosion of the clay bluffs at the eastern end of the park property and threatened existing park structures. A segmented detached breakwater system and beach fill project was built in the fall of 1982 in an effort to protect the area from flooding and erosion by lake storms. The placed beach material was finer graded than was specified and was rapidly lost from the project area; the majority of the material was shoaled in the boat launch area at the western end of the park. As a result of the monitoring program conducted by NCB and CERC, the coastal processes at Lakeshore Park were more clearly defined. Based on the sediment transport

predictions from LEO data, the results from the volume change analysis, and the frequent need in the postproject period to dredge the boat launch area, an east to west direction of sediment transport was indicated. The newly built west groin, therefore, should present an effective trap for littoral sediment, provided it extends out to intercept longshore moving material. In addition, the coarser graded fill should provide a more stable beach.

29. This case example illustrates the difficulties associated with predicting beach response to a particular coastal structure design. Predictions of beach response through probable and extreme wave and water level conditions are critical in the design of a detached breakwater system. Each proposed design must also be evaluated in terms of its impact on adjacent shores. Pope and Dean (1986) present a classification scheme for segmented breakwaters based on various beach responses and some rationale for evaluating the desired response.

30. If, in hindsight, the breakwaters at Lakeshore Park had been constructed closer to shore or with smaller gap spacing, the rate of beach fill loss would have been reduced. If the structures had been constructed close enough to shore, tombolos would have resulted, and the structures would have functioned as artificial headlands. However, there are performance problems associated with the existence of permanent tombolos (i.e., water quality, rip current formation, increased offshore losses, interruption of longshore sediment transport, etc.). The configuration design of the breakwater system must consider both the desired beach response and the average and extreme variability in the wave and water level conditions.

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Table 1

Net Volume Change Between Time Periods

Time Period/ Event	Region 1 384,300*	Region 2 167,600*	Region 3 107,500*	Region 4 90,300*	Region 5 214,800*	Region 6 541,500*
	Net Volume Change in Region, cu yd (Regions defined in Figure 16)					
9/78 - 9/79	-826	+2,175	No data	+1,456	+7,199	+6,522
Net change	-826	+2,175		+1,456	+7,199	+6,522
9/79 - 6/83	+21,648	+1,322	No data	-1,617	-4,653	-4,075
9/82 Fill	-37,000					
6/83 Dredge	-900		+900			
Net change	-16,252	+1,322	?+900	-1,617	-4,653	-4,075
6/83 - 9/84	-5,426	+3,678	+1,510	+768	+6,274	+4,120
6/84 Dredge	-1,000		+1,000			
Net change	-6,426	+3,678	+2,510	+768	+6,274	+4,120
9/84 - 12/84	-3,871	-3,170	+1,112	-581	-1,273	+804
Net change	-3,871	-3,170	+1,112	-581	-1,273	+804
12/84 - 8/85	+912	+2,159	+1,756	+562	+2,687	+1,730
Net change	+912	+2,159	+1,756	+562	+2,687	+1,730
Total change 9/79 - 8/85	-25,637	+3,989	+6,278	-868	+3,035	+2,579

* Represents square foot area of the region.

Table 2

Comparison of Various Breakwater Parameters*

Project	Length of Segments Ls, ft	Length of Gaps Lg, ft	Distance Offshore X, ft	Depth at Structure ds, ft	Ls/Lg	X/ds	Crest Elevation Above LWD ft
Presque Isle (average water level)	125	200-300	70-100	4.8	0.4-0.6	14.6-20.8	+6
Lakeview Park	203	160	280	12.5	1.3	22.4	+8
Lakeshore Park	125	200	330	3.5	0.6	94.3	+6.5

* Adapted from Pope and Dean (1986).